Urban surface material composition from spaceborne imaging spectroscopy data

Marianne Jilge [1,5], Hannes Feilhauer [2,4], Chaonan Ji [1], Carsten Neumann [3], Uta Heiden [1]

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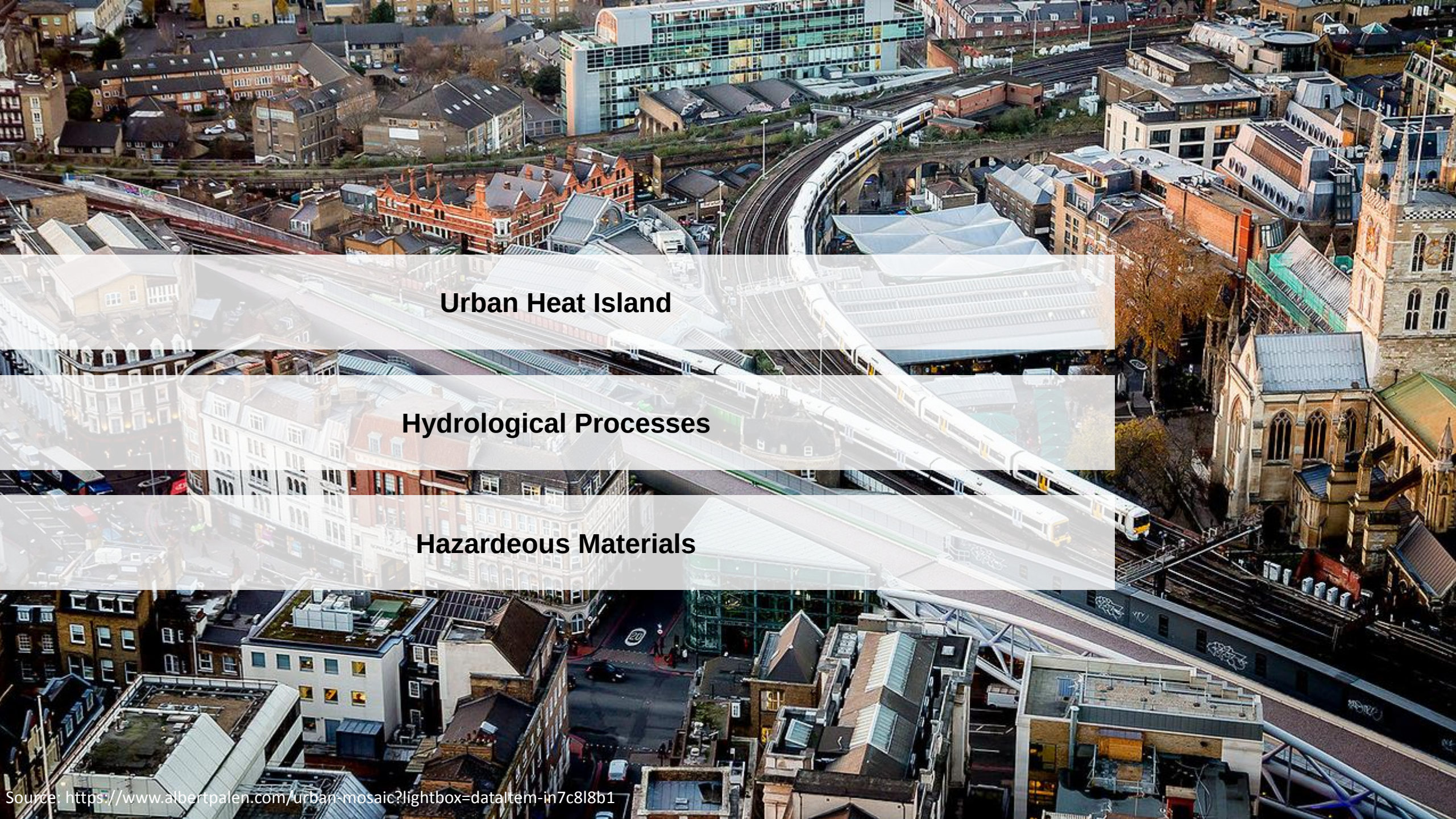
4 FAU Friedrich-Alexander Universität Erlangen-Nürnberg 5 RUB

DLR

Content

1. Can we map urban surface materials from space?

2. What is necessary to enhance urban surface material mapping techniques?



Urban Heat Island

Hydrological Processes

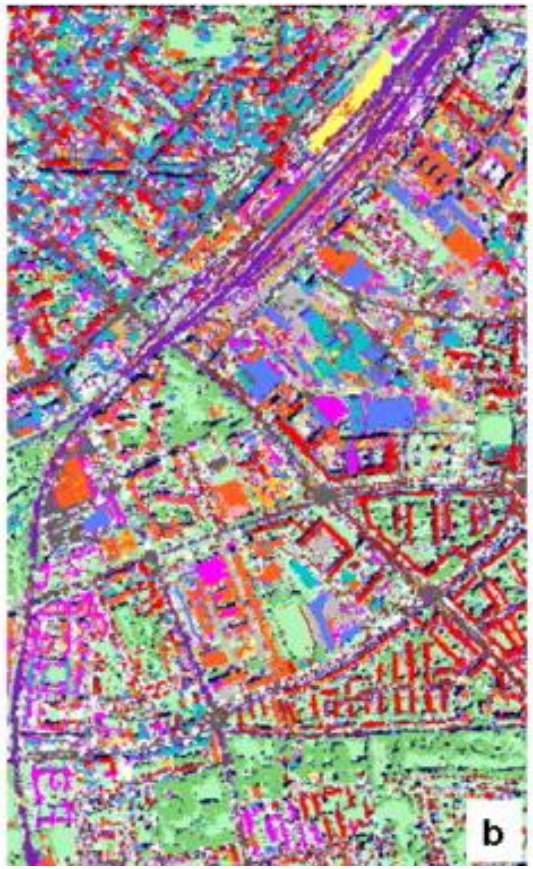
Hazardeous Materials

Source: https://www.albertpalen.com/urban-mosaic?lightbox=dataItem-in7c8l8b1

Challenges using imaging spectroscopy data

Airborne (4 x 4 m pixel)

Detailed material mapping: 20-40 classes



e.g.
Roessner et al. 2001
Segl et al. 2003
Franke et al. 2009
Heldens 2010
Heiden et al. 2012
Demarchi et al. 2014
Priem & Canters 2016

⋮

Modified from
Heiden et al. (2012)

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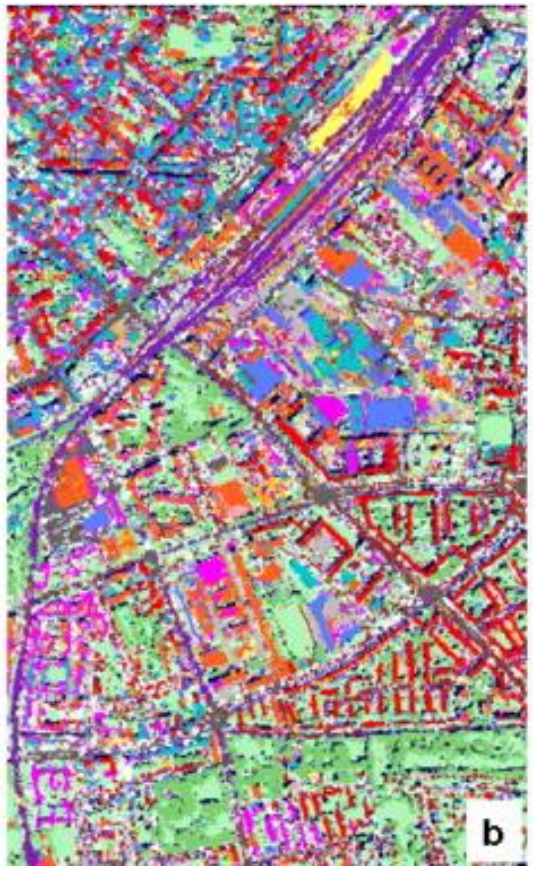

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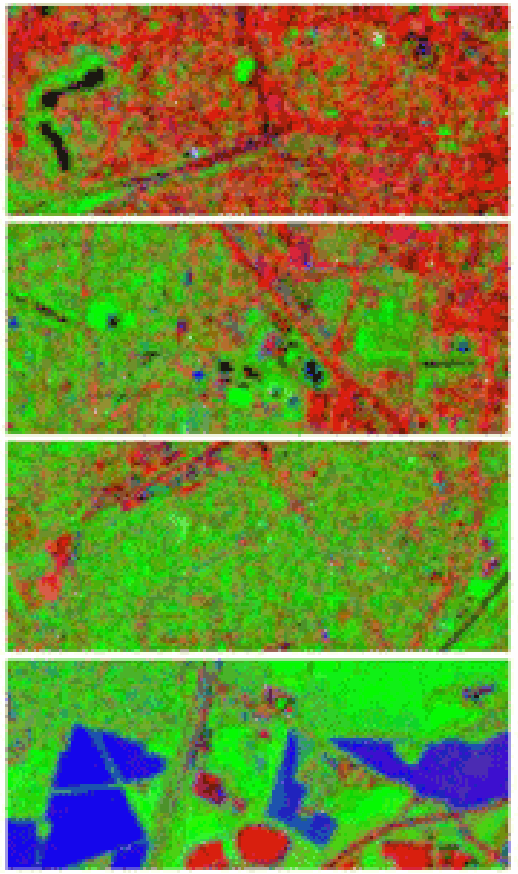
Spaceborne (30 x 30 m pixel)

Mapping of broad categories:
Vegetation – Imperviousness – Soil (VIS)



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Challenges using imaging spectroscopy data

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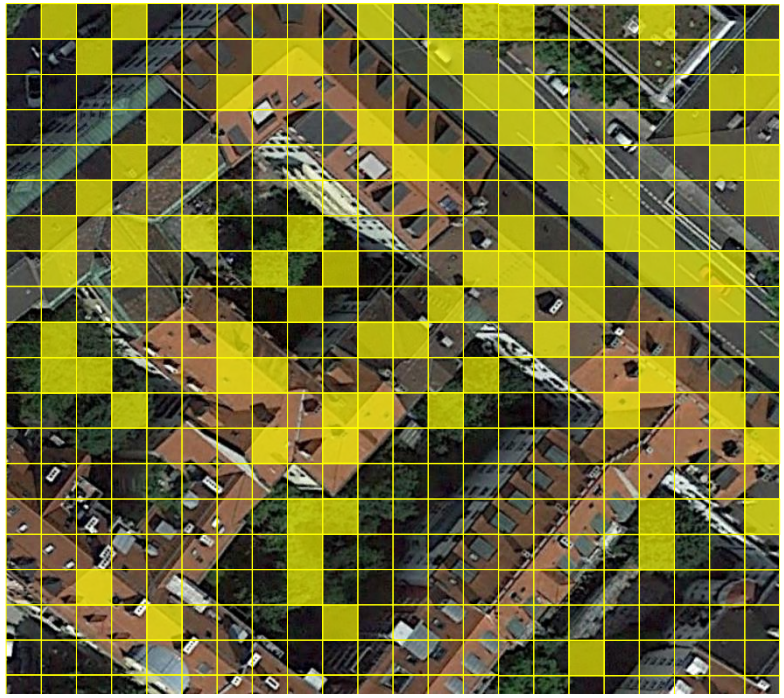


spectrally pure pixel
spectrally mixed pixel

Spaceborne (30 x 30 m pixel)
Mapping of broad categories:
Vegetation – Imperviousness – Soil (VIS)

1. Mapping urban surface materials from space?

Idea

- **Urban areas are formed by history, function and use**
  (WITTIG ET AL., 1998; GILBERT, 1994; MAIER ET AL., 1996)
- **Neighborhoods with specific structural and compositional characteristics**
  (SUKOPP & WITTIG, 1998)
- **„Typical“ surface material composition** (BOCHOW ET AL., 2007; HELDENS 2010)

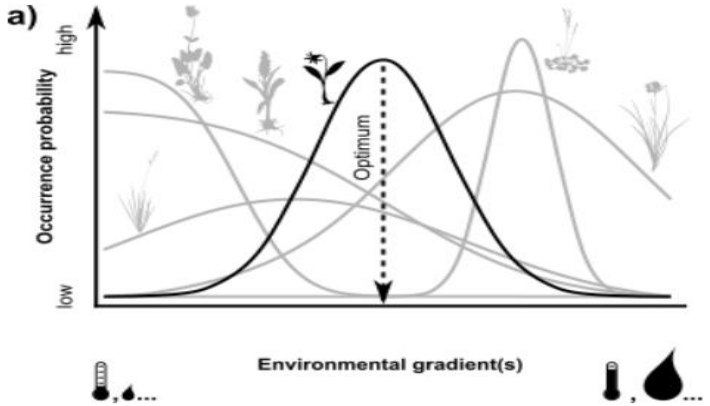
Source: GoogleEarth

Idea – Gradient concept

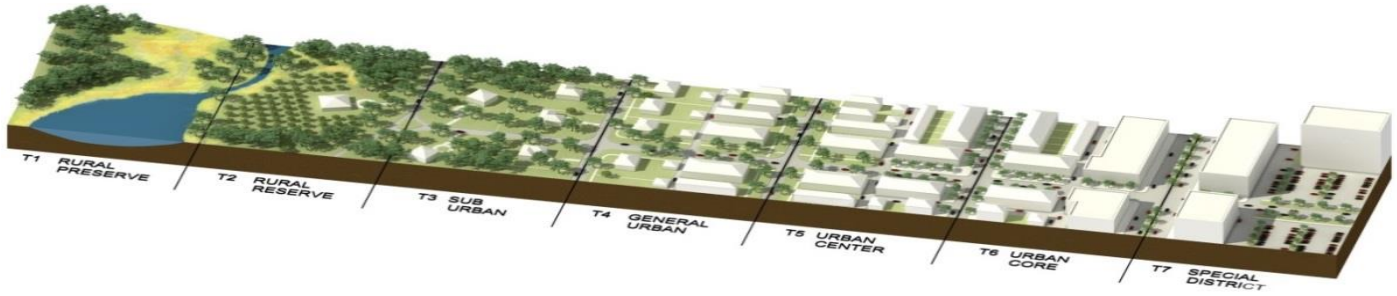
Natural Ecosystem

Feilhauer, 2016

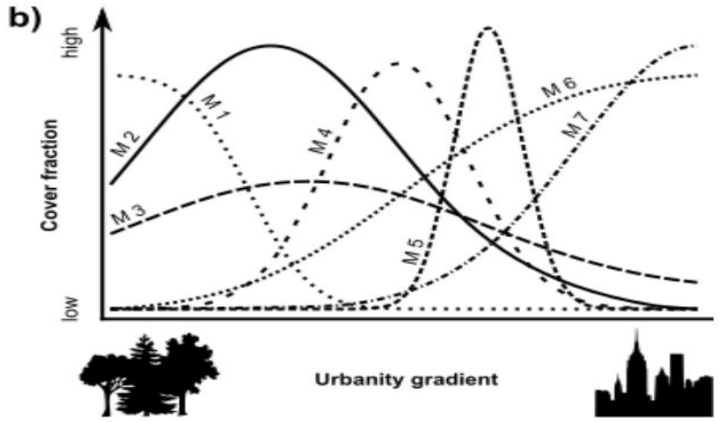
- fuzzy continuum of typical mixtures along gradients
- Optimum occurrence based on environmental conditions



Urban Areas



Source: https://www.zukunft-mobilitaet.net/wp-content/uploads/2016/08/transect-diagramm-new-urbanism-staedtebau-andres-duany-stadtplanung.jpg



Source: Jilge et al. (2019)

1. Mapping urban surface materials from space?

Gradient analysis - Method

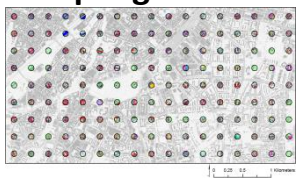
DATA

Surface Material Map

Spaceborne HSI

PRE-PROCESSING

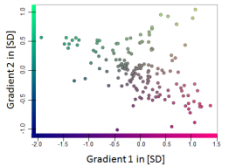
Sampling



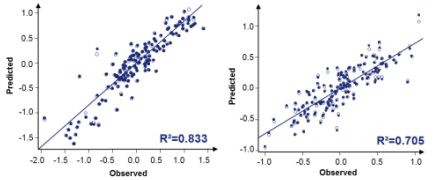
Mean Reflectance

GRADIENT ANALYSIS

Ordination

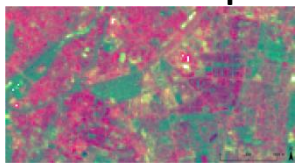


Regression

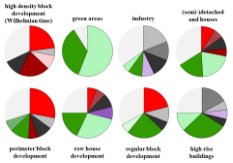


RESULTS

Prediction Map



Surface Material Composition



- Munich, Germany
- HyMap
- June 17 and 25, 2007
- 4 m
- 125 bands (450-2500 nm)

- Munich, Germany
- Simulated EnMAP
- June 17 and 25, 2007
- 30 m
- 162 bands (423-2439 nm)

- Systematic Circular Sampling Scheme
- 153
- 100 m
- 300 m

- Averaged reflectance spectra per band and sample

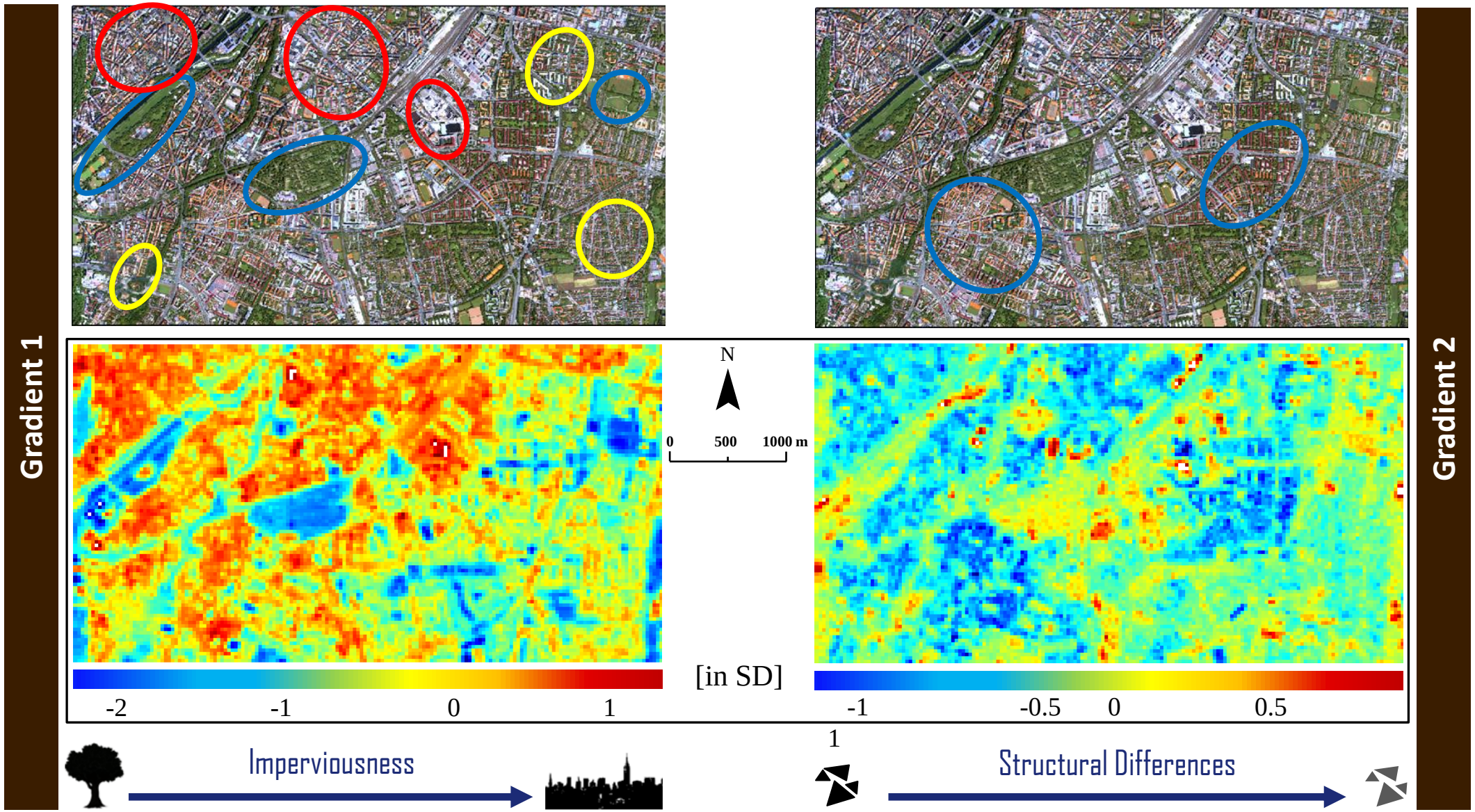
- Detrended Correspondence Analysis (DCA)
- 2 interpretable gradients

- Partial Least Square Regression
- 10 fold cross-validation
- **R^2=0.85** (gradient 1)
  R^2=0.71 (gradient 2)

Jilge, M., Heiden, U., Neumann, C., Feilhauer, H. (2019). Gradients in urban material composition: A new concept to map cities with spaceborne imaging spectroscopy data. Remote Sensing of Environment, 223, pp. 179-193. Elsevier. DOI: 10.1016/j.rse.2019.01.007 ISSN 0034-4257

1. Mapping urban surface materials from space?

Gradient analysis – Prediction map of DCA scores



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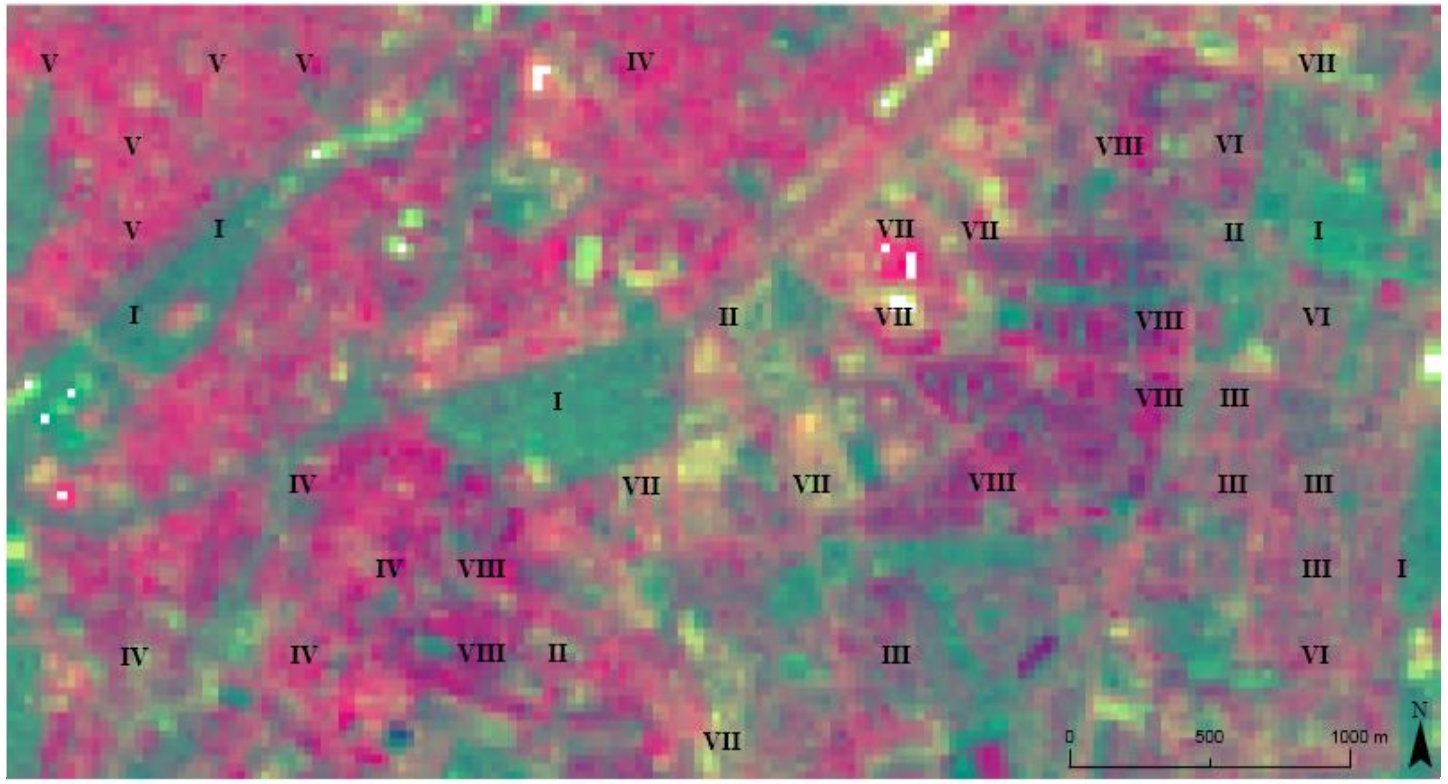
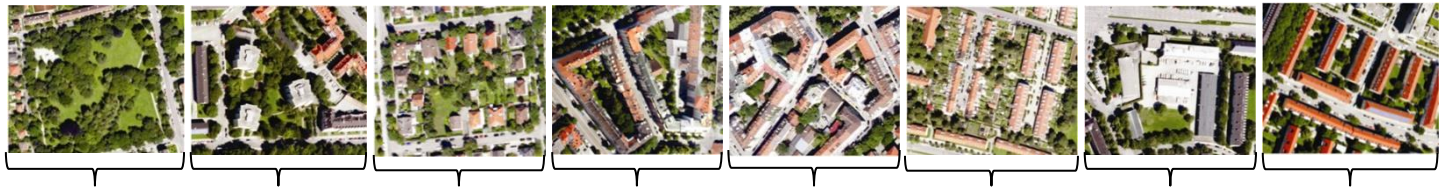
1. Mapping urban surface materials from space?

Gradient analysis – Prediction map of DCA scores (combined)



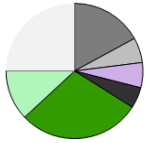


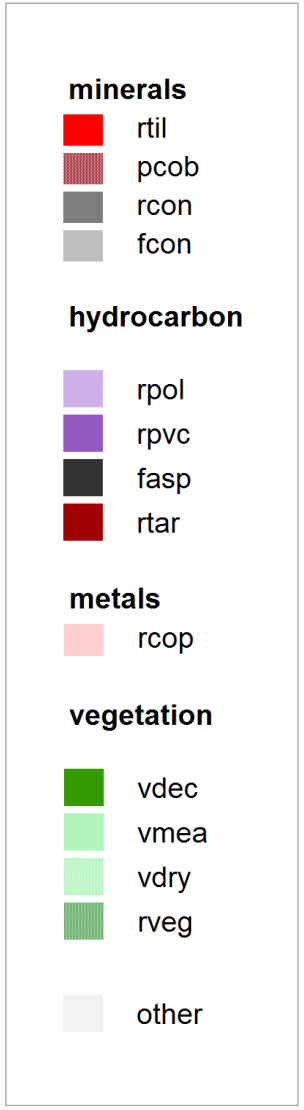
I	II	III	IV	V	VI	VII	VIII
Green areas	*High rise buildings*	*(Semi-) detached houses*	*Perimeter block development*	*High density block development*	*Row house development*	*Industry*	*Regular block development*

- different **material composition** marked by different shades
- patterns can be linked to urban neighbourhoods (e.g. UST)

1. Mapping urban surface materials from space?

Characteristic Material Compositions

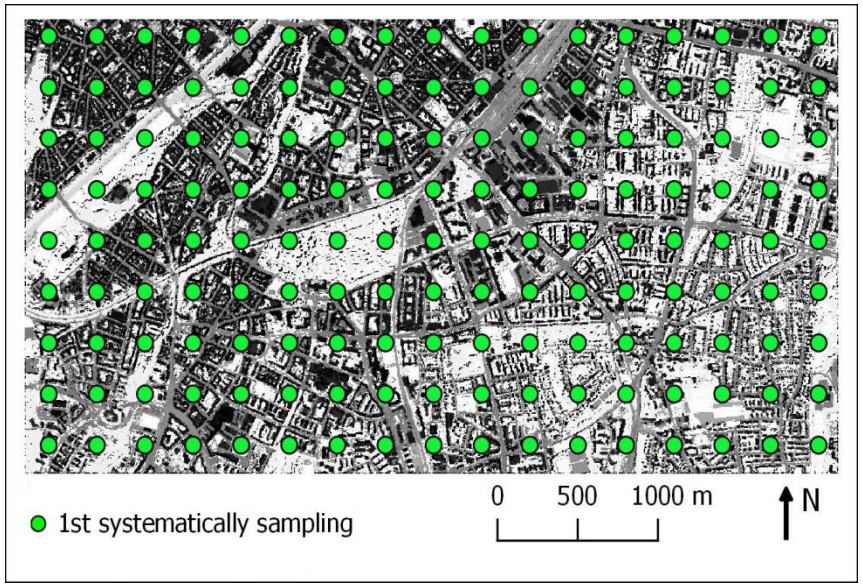
Urban Neighbourhood	Characteristic Composition	Samples
I green areas		
II high rise buildings		
III (semi-)detached houses		
IV perimeter block development		
V high density block development (Wilhelmian time)		
VI row house development		
VII industry		

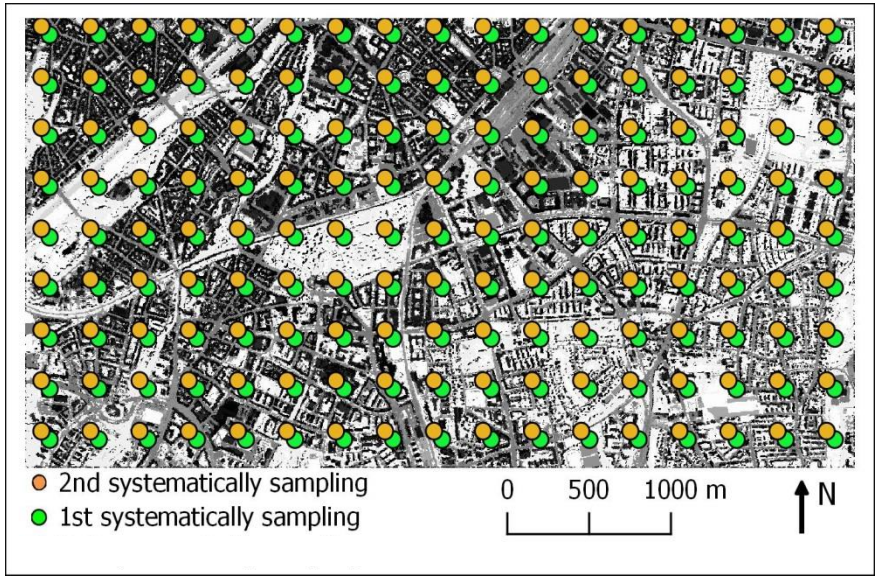


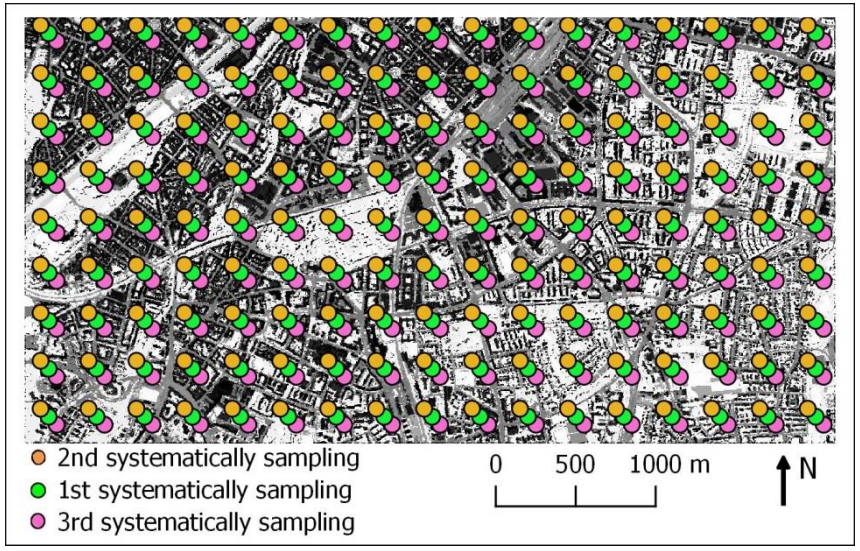
- Dominanting materials per urban structure type
- Generally different material composition of USTs
- Differentation of similar material compositions due to varying cover fractions

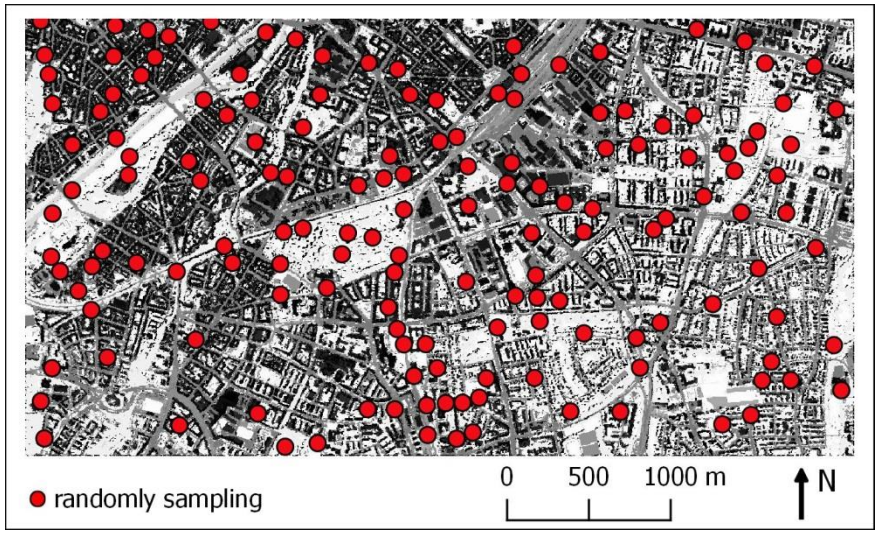
1. Mapping urban surface materials from space?

Way forward









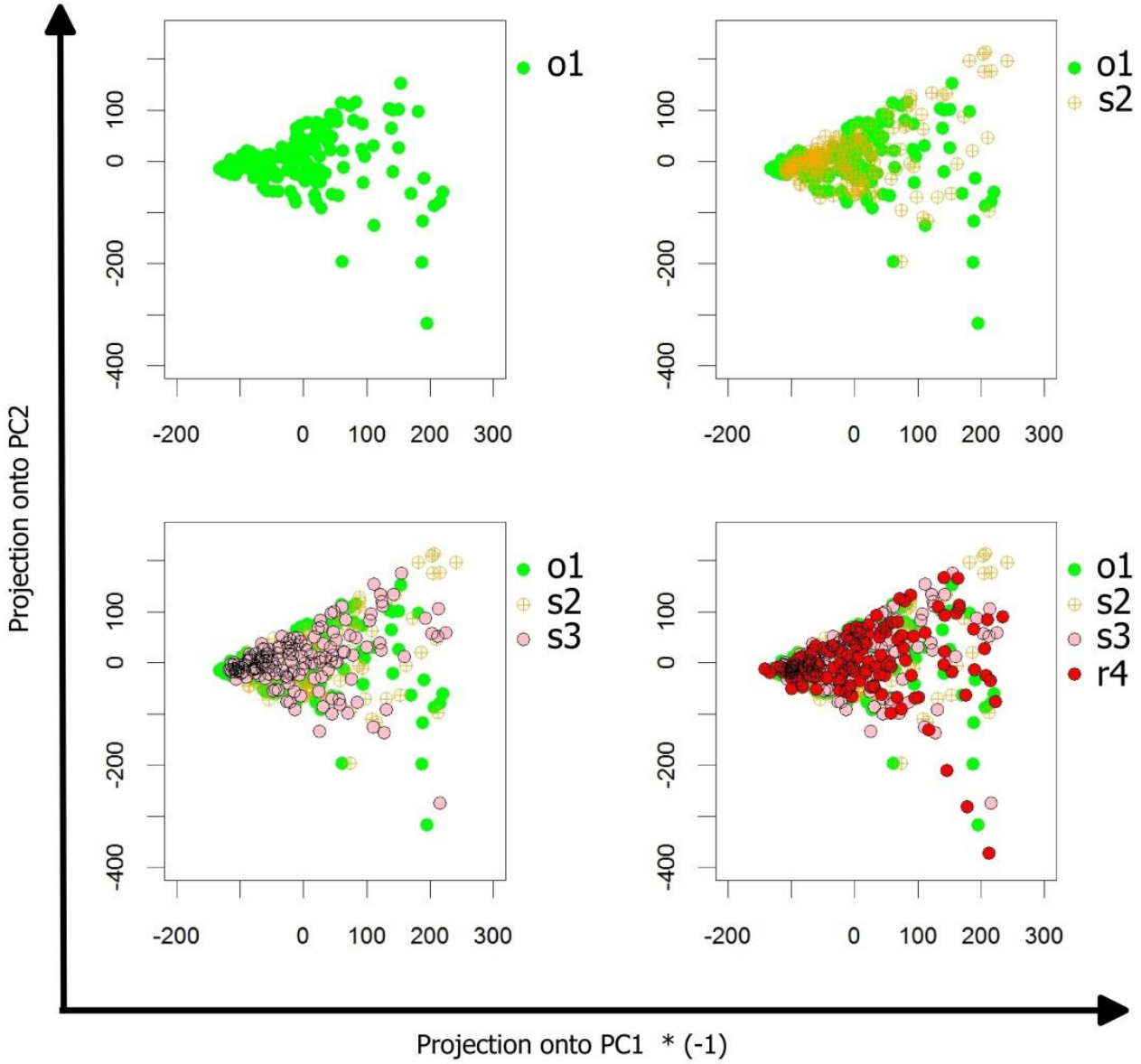
Objective:

- How does gradient space change with sampling?
- Does gradients have the same meaning/pattern?
- Can we transfer regression models to an unknown scene?

1. Mapping urban surface materials from space?

Way forward

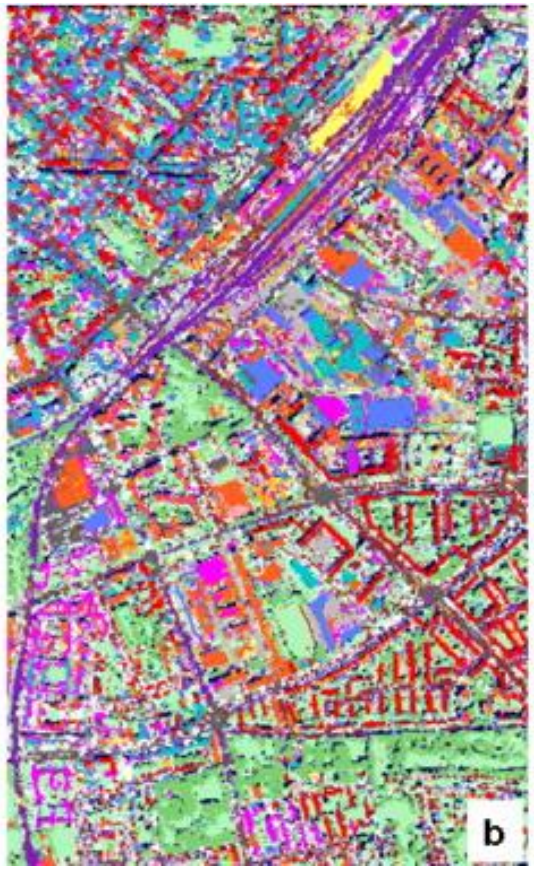
Abbriviation	Full name	Class content (%)				Total pixels
		o1	s2	s3	r4	
rtil	roofing tiles	9	8	9	8	66886
rcon	roofing concrete	7	9	8	7	27440
ralu	aluminum	8	9	10	8	10466
rcop	copper	8	7	9	9	13366
rzin	zinc	8	9	5	9	7607
rpvc	PVC	8	8	7	9	13434
rpol	polyethylene	9	12	9	10	8625
rbit	roofing bitumen	8	10	7	9	14883
rtar	roofing tar	8	8	8	8	29249
rveg	vegetated roof	8	9	8	8	18879
rgra	roofing gravel	11	9	13	7	8206
fcon	concrete	10	8	8	8	42104
fasp	asphalt	8	8	8	8	84854
fkun	synthetic turf	9	5	15	22	3209
pcob	cobblestone	8	9	8	7	47358
prlc	loose chippings	10	8	9	7	20546
pcon	concrete slabs	8	9	9	7	11015
prail	railway tracks	7	9	7	10	10811
praiv	vegetated railway tracks	8	10	7	9	11546
bsan	siliceous sand	9	8	9	9	11765
bsoi	humous soil	6	5	11	8	2978
wriv	river	10	10	5	9	4518
wpon	pond	8	8	8	9	4691
vdec	deciduous trees	8	8	8	8	172784
vlaw	lawn	8	8	7	7	16983
vmea	meadow	9	8	8	9	87525
vdry	dry vegetation	9	8	8	8	35690



What is necessary to enhance urban surface material mapping techniques?

2. What is necessary to enhance urban surface material mapping techniques?

Airborne (4 x 4 m pixel)
Detailed surface material mapping



e.g.
Roessner et al. 2001
Segl et al. 2003
Franke et al. 2009
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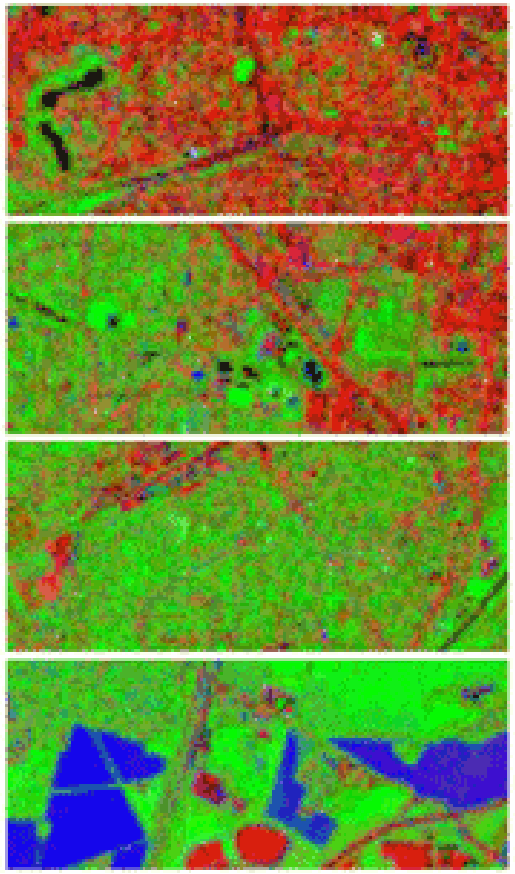
Demarchi et al. 2014
Priem & Canters 201

Modified from Heiden et al. (2012)

Spaceborne (30 x 30 m pixel)
Mapping of broad categories:
Vegetation – Imperviousness – Soil (VIS)



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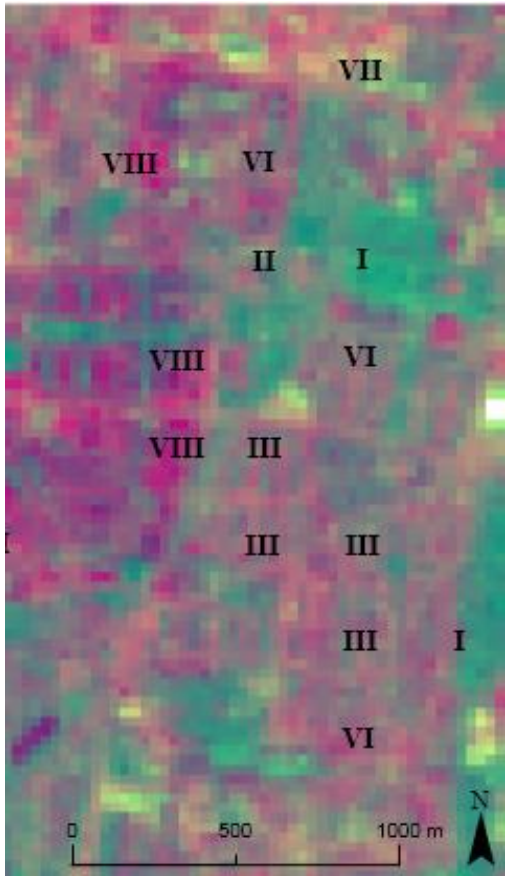
Spaceborne (30 x 30 m pixel)
Mapping of surface
Material Compositions



e.g.
Jilge et al., 2019
Ji et al., (in prep.)

Modified from Jilge et al. (2019)

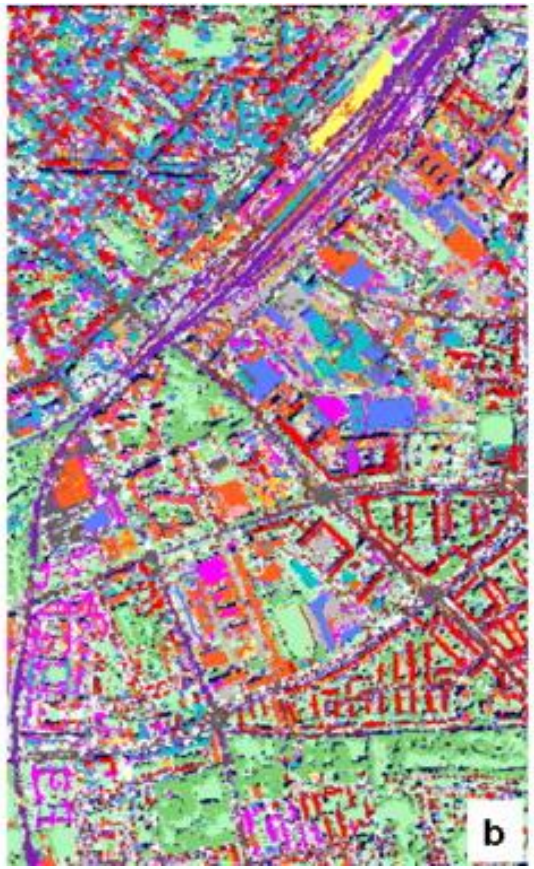
DLR

2. What is necessary to enhance urban surface material mapping techniques?

A common training data base – Urban spectral library

Airborne (4 x 4 m pixel)

Detailed surface material mapping



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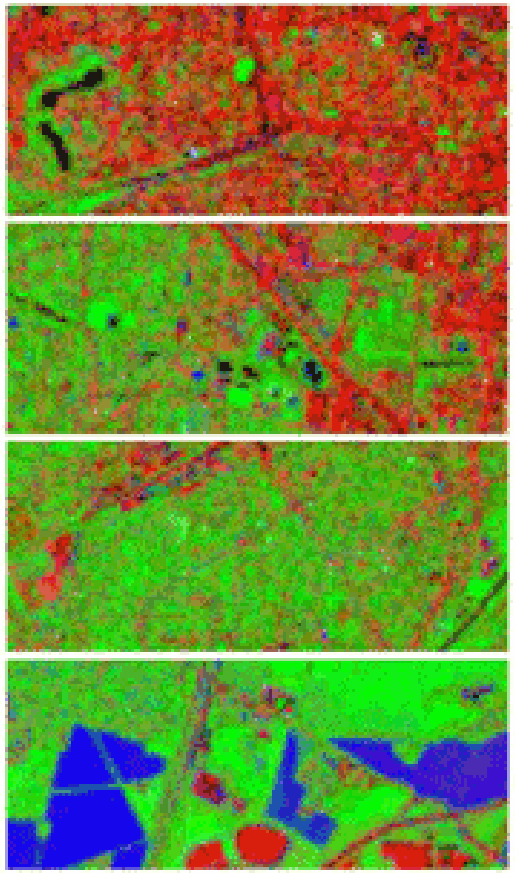

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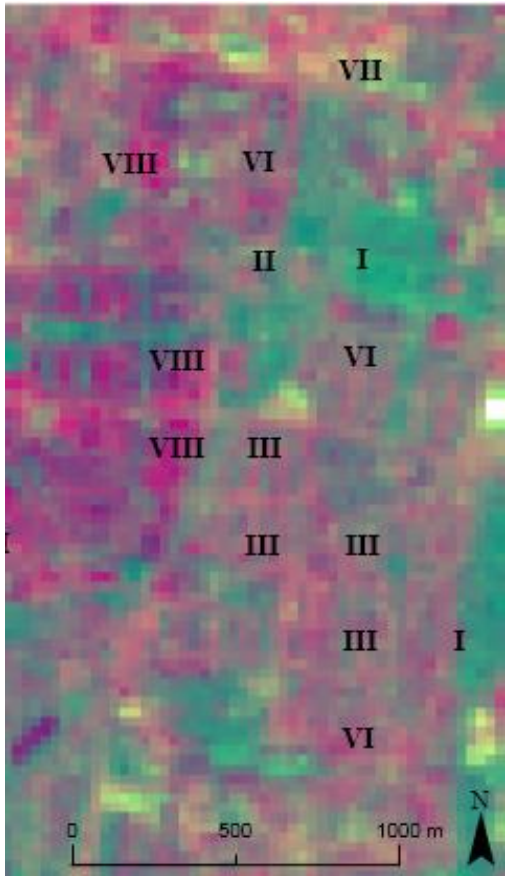

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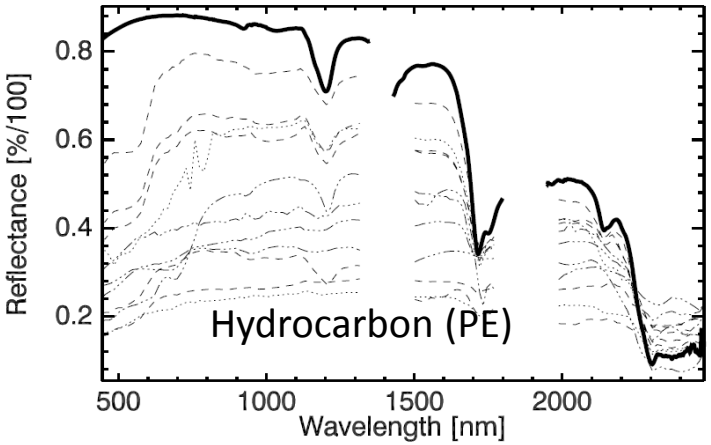
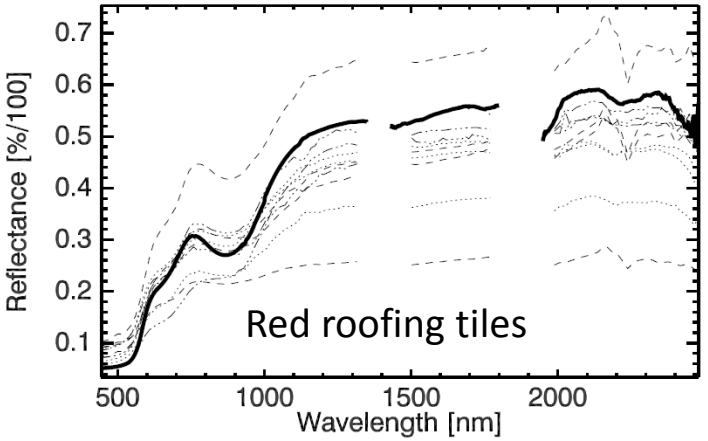
2. What is necessary to enhance urban surface material mapping techniques?

Generic urban spectral library - Challenges

- Large diversity of spectrally different urban surface materials (e.g. color, coating, degradation, …)
- High intra-class spectral variability
- Image spectra instead of lab/field spectra
- Extracting high-quality reference spectra for model training is time-consuming and costly



- Automated endmember extraction methods require expert knowledge for pixel labelling and detect only spectral extrema of material classes



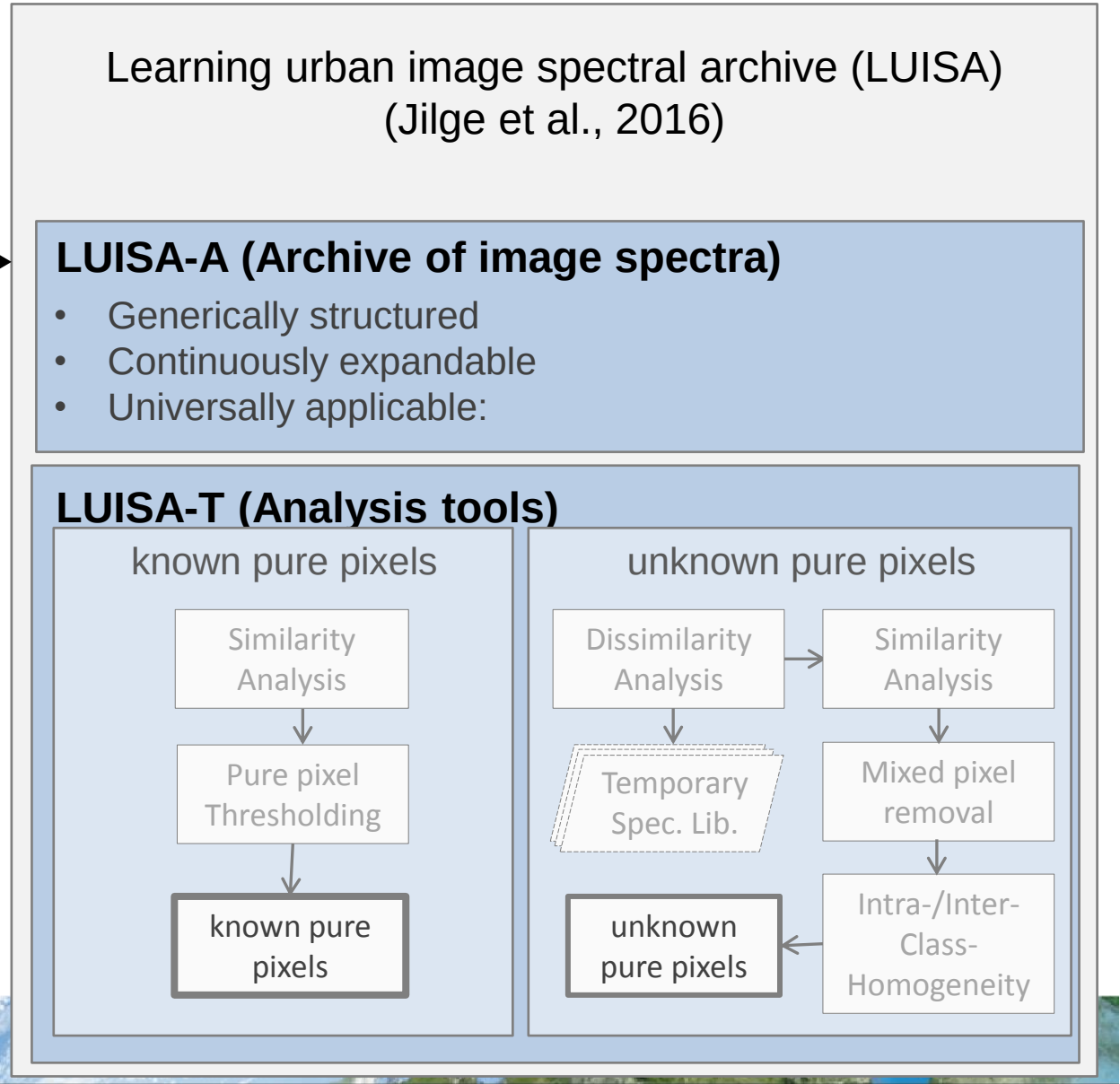
Heiden et al. (2007)

No universally applicable spectral library available!

2. What is necessary to enhance urban surface material mapping techniques?

Generic urban spectral library - Requirements

- Globally applicable library of image spectra
- Techniques capable to handle incompletness of a generic urban library (Jilge et al. 2016, 2017)
- Community agreed set of metadata
- Pruning - Generate relevant image-specific library subsets (Schaaf et al. 2011; Iordache et al. 2014; Degerickx et al. 2017)
- Extraction of multiple endmembers (bundles) per scene component (Somers et al., 2012) to improve unmixing



2. What is necessary to enhance urban surface material mapping techniques?

GENLIB Project (funded by BELSPO)

GENLIB - DEVELOPING A GENERIC FRAMEWORK FOR LIBRARY BASED MULTI-SITE MAPPING OF URBAN AREAS

A SPINOFF OF THE URBANEARS PROJECT

LEAD: VUB, BRUSSELS (FRANK CANTERS)

PARTNERS: KULEUVEN (BEN SOMERS), DLR (UTA HEIDEN)

- WP1: Development of a **data model** and **metadata scheme** for archiving urban image spectra (DLR)
- WP2: Defining a **conceptual framework for management and use** of a GUL
- WP3: **Proof-of-concept** for multi-site/multi-scale urban mapping

Summary and Outlook

- ✓ Determination of material gradients from a heterogeneous urban environment
- ✓ Mapping urban material compositions from 30 m spatial resolution
- ✓ Urban neighbourhoods are delineated by characteristic material compositions
- ✓ No spectrally pure endmembers are necessary to interpret complex spectral mixtures

- ❖ Transferability of results to other / larger urban areas?
- ❖ Need for training data bases -> Generic urban spectral library
- ❖ New project started – GENLIB -> Input from the community and knowledge exchange is very welcome!

Thank you for your attention!

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Ji.Chaonan@dlr.de

http://www.coeser.de/impressions/bilder/hua-hin-06-colored-rooftops-bunte-hausdaecher-christian-oeser.jpg